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Preliminary Assessment
of the
Potential for a
Resource Recovery Project in
Putnam County, Tennessee

COMPLETED

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ORIGINAL

Technical Assistance
Provided by
Tennessee Valley Authority

October 1981

TVA/OP/EDT-81/59

ASSESSMENT FOR POTENTIAL RESOURCE
RECOVERY PROJECT
IN PUTNAM COUNTY, TENNESSEE

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PROLOGUE

The passage of Public Law 94-580, known as the Resource Recovery and Conservation Act of 1976 (RCRA), has placed a tremendous burden on the communities of the United States to identify and implement systems for solid waste management whereby urban and industrial waste can be disposed of in an environmentally acceptable manner. This law, coupled with the national energy crisis, makes it imperative that solid waste be used as a source of materials and energy. Estimates have indicated that over 130 million tons of municipal waste, containing an energy equivalent of over 208 million barrels of crude oil, are generated in the United States each year. Through concentrated efforts to recover energy from waste materials, utilization of these waste resources could result in a reduction in the Nation's dependency on oil.

During recent years attention has been directed toward recovery of energy from solid waste as a means of supplementing dwindling energy supplies and providing alternative disposal methods. In the Tennessee Valley region a need exists for developing, demonstrating, and evaluating alternative disposal methods that meet community needs for solid waste disposal and that are compatible with national goals of resource conservation and environmental protection. Renewed emphasis on energy conservation and recent legislation regarding land disposal of solid waste has focused attention on resource recovery systems as viable and timely alternative methods.

TVA's early involvement with the region's solid waste problems was directed toward filling the broad technological void that existed in the solid waste management field, increasing the capacity of local governments to provide basic services, and marshalling local efforts into a unified

resource development effort. TVA's technical expertise was made available to assist local governments in closing illegal dumps and in developing sanitary landfills and rural bulk container collection systems.

In July 1976, the Tennessee Valley Authority completed a study entitled Study of the Feasibility of a Regional Solid Waste Derived Fuel System in the Tennessee Valley Authority Service Area. This study addressed the feasibility of developing a regional solid waste energy and resource recovery system which would provide solid waste derived fuel for selected existing coal-fired electric generating plants operated by TVA. The study showed at that time negative feasibility for the concept as defined for the stated reason that the cost of collecting and transporting solid waste in the volumes necessary for use in the large TVA generating plants and the cost of retrofitting existing plant boilers to accommodate this type of fuel would be too high. TVA recognized, however, the benefits in conservation of petroleum-based fuels which might be derived through energy recovery from solid wastes on a smaller, more localized scale where the primary fuel (solid waste) would be locally generated and the recovered energy could be locally marketed in the most convenient form (steam or electricity).

As a result of this work, TVA implemented a regional waste-management program to study and assess solid waste management and resource recovery technologies and to advise interested governmental bodies in the TVA region with respect to solid waste management and energy recovery alternatives available to them. The Waste Management Staff of TVA's Energy Demonstrations and Technology Division will render planning and advisory assistance to communities in studying solid waste incineration and energy recovery to reduce the need for landfill operations for disposal of solid waste

materials in the Tennessee Valley region. TVA will also be instrumental in demonstrating new technologies.

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Introduction

The Putnam County landfill situation is becoming critical with only 18 months of usable space remaining before a decision must be made regarding expansion of the landfill. Local officials were therefore prompted to request technical assistance from TVA in the form of a resource recovery feasibility study. This study would offer possible alternatives to land-filling by describing various ways in which municipal solid waste could become a usable fuel source. This study would (1) include a description of the present solid waste disposal operation, and (2) outline various options available in the area of resource recovery. Cost estimates would also be included in this study.

Solid Waste Inventory

After several meetings among local officials and TVA's Waste Management Branch personnel, field work for this study was initiated in April 1981. At this time accurate solid waste data was not available. Therefore, a two-week solid waste weighing program was begun on May 18. Results of this program show that 841 tons of solid waste were delivered to the landfill during the two-week period. Therefore, 420 tons of waste per week or 60 tons per day on a 7-day basis would be available for processing. Approximately 2,100,000 to 2,646,000 pounds of steam could be produced from this amount of solid waste weekly; 300,000 to 529,000 pounds daily; or 12,500 to 22,000 pounds hourly in a waste processing facility. Disposal cost incurred by the county for 1980-81 is approximately \$6.75/ton.

The population of Putnam County is 47,601, which is expected to increase to 50,200 by 1990.* The present waste quantity delivered to this area's landfill is 22,000 tons annually. By 1990, this amount should increase to 23,700 tons per year.

Energy User Inventory

An inventory of prospective energy customers was taken in Putnam County. A TVA representative visited various industrial and institutional establishments to collect data concerning steam demand rates for industrial processing, hot water uses, and space heating requirements. Table 1 lists those establishments which were contacted and shows information received from each.

The results of this survey indicate that there are several steam users in Putnam County with some process steam requirements, space heating, and hot water needs. However, none would be able to utilize all available steam on a continuous year-round basis. It must be noted that in order to maintain a resource recovery system in a cost-effective manner, most of the available steam manufactured from the area's municipal solid waste must be marketed on a continuing basis.

As Table 1 indicates, the largest potential steam customer, Tennessee Technical University (TTU), could utilize all available steam manufactured from the area's solid waste during the winter months, but could only use 1/6 to 1/4 of the total amount during the summer. The industry with the second largest steam demand, Norwalk (wood materials manufacturer), uses

*U.S. Bureau of Economic Analysis, Projections of Economic Activity in Tennessee.

TABLE 1

POTENTIAL RESOURCE RECOVERY ENERGY CUSTOMERS IN PUTNAM COUNTY

Establishment	Steam Use	Fuel	Pressure	No. of /Max. Rated Boilers Capacity	Steam Demand	
					Rate (lb/hr)	Schedule
Tennessee Technological University	Space Heating	Gas	80	2/ 5,000 lb/h	4,000- 6,000	May-Oct/24 h/da
	Hot Water	Oil		2/68,000 lb/h	8,000-32,000	Nov-Apr/24 h/da
				1/34,000 lb/h		
Cookeville General Hospital	Space Heating	Gas	40	2/175 hp	12,000	Nov-Apr/24 h/da
	Hot Water	Oil			900	May-Oct/24 h/da
Norwalk	Process	Scrap Wood	135	2/25,000 lb/h	14,500	May-Oct/24 h/da
	Space Heating	(in-house) Gas (backup)			20,000	Nov-Apr/24 h/da
Tutco	None					
Porelon	Process (occasional)		15			
Dixie Home Furniture	None					
Oster	None					
Fleetguard	Space Heating			2/750 hp		Oct-Mar/24 h/da
Russell Stover Candy	Process	Oil	105	2/20,000 lb/h	12,000	Nov-Apr/5 da/wk
	Space Heating				10,000 3,000	May-Oct/5 da/wk Weekends

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its own woodwaste as fuel for steam production. Therefore, the dependence on expensive fuels (oil and gas) is non-existent.

Cookeville General Hospital has two boilers which provide steam for both hot water and space heating. Steam production is at the relatively low pressure of 40 psi with seasonal demand rates varying between 900 lb/hr in summer and 12,000 lb/hr in winter. Cookeville General Hospital is located adjacent to TTU. Though the steam demand of TTU alone is great enough to utilize all of Putnam County's available steam in winter, even when combined with the steam demand of Cookeville General in the summer months, no more than about 25 percent of the total steam could be utilized.

Another industry located in Putnam County, Fleetguard, is a steam user but does not have the demand size needed to utilize all available steam. Fleetguard's only steam use is in the form of space heating during winter months.

The Russell Stover Candy Company, located on Highway 111 near Algood, uses process steam at a rate of 10,000 pounds per hour on a 24-hour basis. Steam is also used for heating needs during winter months, thus increasing the total utilization rate to 12,000 pounds per hour. The plant operating schedule is 24-hours per day, 5-days per week. Boiler operation is cut back drastically on weekends to a rate of 3,000 pounds per hour. The steam demand schedule of Russell Stover Candy equals about 70 percent of the available steam manufactured from municipal solid waste in Putnam County. It should be noted that Russell Stover Candy may be expanding in the near future which could result in a doubling of the present steam demand rate.

Project Proposal

The greatest likelihood for a successful resource recovery project in Putnam County centers around the steam requirement of Russell Stover Candy Company. The proposed project would involve building an incineration system with steam boilers on a five-acre tract adjoining Russell Stover located on Highway 111 near Algood. This is the most appropriate site in Putnam County because the steam requirement is a constant one of 10,000 pounds per hour on a 24-hour basis and this steam rate increases by 20 percent in winter for heating needs. Although the steam requirement at Tennessee Technological University (TTU) is much greater on a yearly basis than that of Russell Stover, the summer demand rate is only 20 percent of the total available steam. Therefore, project costs would become prohibitive due to the elimination of maximum steam revenues for almost half of an entire year if a waste processing facility were located on the TTU campus.

The steam demand schedule of Russell Stover equals about 70 percent of the total available steam manufactured from municipal solid waste in Putnam county. But with possible plans for expansion at Russell Stover, the steam requirement could double, thus offering potential future utilization of 100 percent of the available steam.

Eighty-four tons of solid waste per day (five days/week) are collected in the Putnam County study region. Approximately 12,500 to 22,000 pounds of steam per hour can be produced from this amount of waste if a resource recovery facility is operated on the same schedule as Russell Stover Candy Company.

For purposes of this assessment, cost analyses have been computed based on present steam uses at Russell Stover and 1984 projected waste quantities along with a hypothetical situation of 100 percent steam sales should future expansion actually materialize.

A system capable of processing 100 tons of waste per day should be adequate for Putnam County through the 1990's based on present waste loads and collection practices, as well as future projected waste quantities.

All solid waste delivered to a resource recovery facility would be handled inside and out of view of adjacent property owners. Incoming refuse trucks are unloaded directly onto a tipping floor or into a storage pit which can hold a minimum of three days' supply of waste. Rubber-wheeled front loaders or a crane then transfer the waste from the storage area into the combustion units. Odor is not usually a problem because combustion air for the incinerator is drawn from the waste storage area so that the odor is destroyed when it passes through the incinerator.

The combustor process does not require auxiliary fuel except for unit startup load following and, in some systems, for pollution control. The solid waste is reduced in volume by 90 percent and in weight by 75 percent. The hot gases resulting from the combustion process are passed through a boiler system to produce steam. The combustion gases are cooled by the heat exchangers and then cleaned by the air pollution control system to meet Federal and State air quality control criteria. By the time the gases exit the stack, no visible soot or smoke is present. A conceptual drawing of a typical solid waste heat recovery facility is shown in Figure 1 in Exhibit A.

A backup landfill must be maintained so as to allow for disposal of system residues (10 percent of original volume; 25 percent of original weight) plus occasional disposal of raw waste when there is a plant outage.

The cogeneration of electricity could also be an added option to Putnam County's resource recovery project, extending the utilization of municipal solid waste as a fuel source. Approximately 5,000 to 6,300 pounds

of steam can be manufactured from one ton of solid waste; and with the addition of a turbogenerator to the recovery facility, this steam can also produce electricity. The amount of electricity produced is dependent upon the type of turbine used in the system and the steam conditions required by the steam users. Assuming that high-pressure steam is manufactured from this area's solid waste, a backpressure turbine could then produce electricity. The exit low-pressure steam would be sold to industrial customers.

The cost analysis done for this assessment includes two types of waste processing technologies. The first computation is for the controlled air modular system and the second is for the more expensive modular waterwalled system. The waterwalled energy recovery system is the most appropriate technology for manufacturing high-pressure steam to be used with a turbogenerator for electrical cogeneration. Though it is more expensive, the added revenues can serve to offset the costs. However, the practicality of the addition of electrical cogeneration to the resource recovery project should be evaluated when and if the expansion of the Russell Stover Candy Company takes place. The future process steam parameters (lbs/hour, psi) will determine the suitability of one system over another which in turn determines the feasibility of the added option (electrical cogeneration) to the basic project.

Table 2 gives the capital, owning, and operating costs for a resource recovery facility using the modular controlled air technology. Table 3 lists the life cycle cost analysis (15 years) for a system of this type based on the marketing condition (a 66 percent steam sale) beginning in 1984 with the corresponding projected waste load. Table 4 follows with a hypothetical life cycle cost analysis based on a 100 percent steam market. Tables 5, 6, and 7, respectively, list the same cost computations for the

modular waterwalled system. Life cycle costs are geared to a 20-year period. See Exhibit A for a detailed description of incineration-waste heat recovery systems.

TABLE 2

COST ESTIMATE FOR 100 TPD MODULAR CONTROLLED
AIR INCINERATOR WITH STEAM PRODUCTION FOR
PUTNAM COUNTY, TENNESSEE

1984 Tonnage - 23,000

I. Project Cost

A. Site Development	\$ 350,000
B. Land	100,000
C. Plant Building	550,000
D. Incinerator/Boiler/Pollution Control & Auxiliaries, Installed	3,300,000
E. Distribution System (Assume 1000')	220,000
F. Engineering; Administration; Startup; Testing	275,000
G. Bond Financing Expense	193,000
H. Construction Interest Less Investment Earnings	440,000
I. Contingency	495,000
J. Bond Reserve Fund	<u>1,686,000</u>
TOTAL BOND ISSUE	\$7,609,000

II. Annual Project Costs

A. Annual Owning Cost (15 yrs. @ 12%; CRF = .1468)	\$1,117,000
B. Operating and Maintenance Costs	
1. Personnel	\$300,000
2. Water & Chemical	16,000
3. Auxiliary Fuel	17,000
4. General & Administrative	50,000
5. Utilities	78,000
6. Ash Disposal	22,000
7. Maintenance	<u>86,000</u>
SUBTOTAL	<u>\$ 569,000</u>
TOTAL ANNUAL PROJECT COST	\$1,686,000

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TABLE 3

LIFE CYCLE COST ANALYSIS - CONTROLLED AIR
ENERGY RECOVERY SYSTEM
PUTNAM COUNTY - 74% STEAM SALES

	<u>1984</u>	<u>1989</u>	<u>1994</u>	<u>1998</u>
A. Annual Tonnage	23,000	23,580	24,176	24,663
B. Annual Owning Cost	\$ 1,117,000	\$ 1,117,000	\$ 1,117,000	\$ 1,117,000
C. Annual Operating Cost (escalated at 8%)	\$ 569,000	\$ 836,000	\$ 1,228,000	\$ 1,671,000
D. Total Annual Cost	\$ 1,686,000	\$ 1,953,000	\$ 2,345,000	\$ 2,788,000
E. Annual Steam Sales (lbs)	76,128,000	76,128,000	76,128,000	76,128,000
F. Annual Steam Revenues*	\$ 666,000	\$ 1,174,000	\$ 2,069,000	\$ 3,255,000
G. Interest on Bond Reserve**	\$ 202,000	\$ 202,000	\$ 202,000	\$ 202,000
H. Net Cost (Profit)	\$ 818,000	\$ 577,000	\$ 74,000	\$ (669,000)
I. Net Cost (Profit) per Ton of Waste	\$ 35.55	\$ 24.46	\$ 3.07	\$ (27.14)

*Assumes \$8.75/1,000 lbs steam in 1984.

**Assumes 12 percent interest rate.

TABLE 4

LIFE CYCLE COST ANALYSIS - CONTROLLED AIR
ENERGY RECOVERY SYSTEM
PUTNAM COUNTY - 100% STEAM SALES

	<u>1984</u>	<u>1989</u>	<u>1994</u>	<u>1998</u>
A. Annual Tonnage	23,000	23,580	24,176	24,663
B. Annual Owning Cost	\$ 1,117,000	\$ 1,117,000	\$ 1,117,000	\$ 1,117,000
C. Annual Operating Cost (escalated at 8%)	\$ 569,000	\$ 836,000	\$ 1,228,000	\$ 1,671,000
D. Total Annual Cost	\$ 1,686,000	\$ 1,953,000	\$ 2,345,000	\$ 2,788,000
E. Annual Steam Sales (lbs)	103,500,000	106,114,000	108,793,000	110,985,000
F. Annual Steam Revenues*	\$ 906,000	\$ 1,636,000	\$ 2,957,000	\$ 4,746,000
G. Interest on Bond Reserve**	\$ 202,000	\$ 202,000	\$ 202,000	\$ 202,000
H. Net Cost (Profit)	\$ 578,000	\$ 114,000	\$ (813,000)	\$ (2,160,000)
I. Net Cost (Profit) per Ton of Waste	\$ 25.13	\$ 4.85	\$ (33.65)	\$ (87.58)

*Assumes \$8.75/1,000 lbs steam in 1984.

**Assumes 12 percent interest rate.

TABLE 5

COST ESTIMATE FOR 100 TPD MODULAR WATERWALL
INCINERATOR WITH STEAM PRODUCTION FOR
PUTNAM COUNTY, TENNESSEE

1984 Tonnage - 23,000

I. Project Cost

A. Site Development	\$ 605,000
B. Land	100,000
C. Plant Building	550,000
D. Incinerator/Boiler/Pollution Control & Auxiliaries, Installed	4,125,000
E. Distribution System (Assume 1000')	220,000
F. Engineering; Administration; Startup; Testing	330,000
G. Bond Financing Expense	220,000
H. Construction Interest Less Investment Earnings	605,000
I. Contingency	660,000
J. Bond Reserve Fund	<u>1,841,000</u>
TOTAL BOND ISSUE	\$9,256,000

II. Annual Project Costs

A. Annual Owning Cost (20 yrs. @ 12%; CRF = .1339)	\$1,239,000
B. Operating and Maintenance Costs	
1. Personnel	\$300,000
2. Water & Chemical	12,000
3. Auxiliary Fuel	11,000
4. General & Administrative	59,000
5. Utilities	112,000
6. Ash Disposal	22,000
7. Maintenance	<u>86,000</u>
SUBTOTAL	<u>\$ 602,000</u>
TOTAL ANNUAL PROJECT COST	\$1,841,000

TABLE 6

LIFE CYCLE COST ANALYSIS - MODULAR WATERWALLED
ENERGY RECOVERY SYSTEM
PUTNAM COUNTY - 53% STEAM SALES

	<u>1984</u>	<u>1989</u>	<u>1994</u>	<u>1999</u>	<u>2003</u>
A. Annual Tonnage	23,000	23,580	24,176	24,787	25,286
B. Annual Owning Cost	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000
C. Annual Operating Cost (escalated at 8%)	\$ 602,000	\$ 885,000	\$ 1,300,000	\$ 1,910,000	\$ 2,598,000
D. Total Annual Cost	\$ 1,841,000	\$ 2,124,000	\$ 2,539,000	\$ 3,149,000	\$ 3,837,000
E. Annual Steam Sales (lbs)	76,128,000	76,128,000	76,128,000	76,128,000	76,128,000
F. Annual Steam Revenues*	\$ 666,000	\$ 1,174,000	\$ 2,069,000	\$ 3,646,000	\$ 5,737,000
G. Interest on Bond Reserves**	\$ 221,000	\$ 221,000	\$ 221,000	\$ 221,000	\$ 221,000
H. Net Cost (Profit)	\$ 954,000	\$ 729,000	\$ 249,000	\$ (718,000)	\$ (2,121,000)
I. Net Cost (Profit) per Ton of Waste	\$ 41.48	\$ 30.90	\$ 10.29	\$ (28.98)	\$ (83.88)

*Assumes \$8.75/1,000 lbs steam in 1984.

**Assumes 12 percent interest rate.

TABLE 7

LIFE CYCLE COST ANALYSIS - MODULAR WATERWALLED
ENERGY RECOVERY SYSTEM
PUTNAM COUNTY - 100% STEAM SALES

	<u>1984</u>	<u>1989</u>	<u>1994</u>	<u>1999</u>	<u>2003</u>
A. Annual Tonnage	23,000	23,580	24,176	24,787	25,286
B. Annual Owning Cost	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000	\$ 1,239,000
C. Annual Operating Cost (escalated at 8%)	\$ 602,000	\$ 885,000	\$ 1,300,000	\$ 1,910,000	\$ 2,598,000
D. Total Annual Cost	\$ 1,841,000	\$ 2,124,000	\$ 2,539,000	\$ 3,149,000	\$ 3,837,000
E. Annual Steam Sales (lbs)	129,600,000	132,873,000	136,228,000	139,668,000	142,482,000
F. Annual Steam Revenues*	\$ 1,134,000	\$ 2,049,000	\$ 3,702,000	\$ 6,689,000	\$ 10,738,000
G. Interest on Bond Reserves**	\$ 221,000	\$ 221,000	\$ 221,000	\$ 221,000	\$ 221,000
H. Net Cost (Profit)	\$ 486,000	\$ (146,000)	\$ (1,384,000)	\$ (3,761,000)	\$ (7,122,000)
I. Net Cost (Profit) per Ton of Waste	\$ 21.13	\$ (6.21)	\$ (57.26)	\$ (151.75)	\$ (281.64)

*Assumes \$8.75/1,000 lbs steam in 1984.

**Assumes 12 percent interest rate.

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EXHIBIT A

ENERGY AND RESOURCE RECOVERY TECHNOLOGY ALTERNATIVES

INCINERATION-WASTE HEAT RECOVERY SYSTEMS

Incineration is the process of thermal combustion which reduces the volume of solid waste while producing inoffensive gases and ash by the application of the combustion process. Municipal incinerators are designed for self-sustained combustion of municipal solid waste under controlled conditions that maximize volume reduction while minimizing the emission of pollutants.

Incineration systems, once considered an important advance in sanitary refuse disposal and then criticized as an air and water polluter, are now undergoing intensive technical development to meet new, high standards of air and water pollution control. While technology development of incineration systems continues, the public at large has tended to mistrust this method of solid waste disposal. However, current fossil fuel shortages and the recognition of the energy value potential of municipal refuse has created an interest in these advanced systems of incineration which incorporate heat or energy recovery systems.

An incineration system operating at temperatures of 1300° to 2000° Fahrenheit and at a loading rate that allows time for complete combustion can convert municipal refuse to an inorganic residue containing metal, glass, and ash. With proper cleaning and filtering of stack exhaust, air pollution would be almost nonexistent; and with added attention to the aesthetics of exterior design and landscaping, public acceptance could be assured.

Modular Controlled Air Incinerators

The design of some municipal incinerators is based on the controlled air combustion principles. Two refractory-lined and insulated chambers,

designated primary and secondary, are used for the combustion process; and a refractory-lined stack is used to duct the exhaust gases to the atmosphere. Controlled air incinerators were first commercially available in the United States during the early 1960's. However, substantial acceptance of their concept was not reflected in the marketplace until the last 1960's or early 1970's.

The controlled air system employs two chambers to accomplish the incineration process. The lower chamber is designated as the primary chamber, and the upper chamber as the secondary chamber. In the front of each primary chamber is a hydraulic ram feeder where the unsorted municipal solid waste is deposited and metered into the primary chamber. Ignition takes place in the primary chamber. Once preset conditions of temperature and time have been achieved, the primary chamber auxiliary fuel burners turn off automatically and the combustion system is self-sustaining.

These systems were developed to minimize particulate emission on incineration equipment. In order for these units to perform in a nonpolluting mode, the conditions in the two chambers must be controlled. A reducing atmosphere (insufficient oxygen for complete combustion) is maintained in the primary chamber, and the gas velocities are kept very low to minimize the entrainment of particulates in the effluent gas stream. This system is sometimes called "starved air" incineration since the lower chamber's operating characteristics provide for a partial pyrolysis system.

The heat release in the lower chamber is controlled by limiting the introduction of combustion air to an amount which provides for partial oxidation of the waste in the chamber. The heat release is sufficient to provide self-sustained partial oxidation reactions. The gas velocity in the lower chamber is influenced by several factors. The gas, which evolves

from this chamber, is a result of the interaction of the air, the auxiliary fuel, and the oxidation and volatilization products from the waste. The quantity of gas from the waste can vary substantially depending upon the chamber conditions and the waste; and this could, therefore, significantly alter the lower chamber velocity. The waste is moved through the primary chamber either by stepped transfer rams, by drag chains, or by the injection of additional waste material pushing the already burning waste further to the rear of the unit.

The effluent gas stream from the lower chamber is introduced into the secondary chamber through a zone of turbulent air flow where ignition takes place and the combustion process is completed. The primary function of the secondary chamber is to complete the oxidation reaction of the combustible products as they are received from the lower chamber. In order to accomplish this, conditions in the chamber must be controlled within rather narrow bands from inputs, which vary widely. This is accomplished by maintaining an oxidizing atmosphere (excess air) and by modulating both air and auxiliary fuel in the secondary chamber. The interjection of auxiliary fuel and maintaining retention time in the secondary chamber will ensure complete oxidation of the combustible material in the gas stream.

It is important that the temperatures in the upper chamber are maintained at less than 2500°F in order to minimize nitrogen oxide production to ensure equipment durability and of at least 1800°F in order to stabilize an adequate reaction rate to complete the combustion process. The primary means of controlling the temperatures in the secondary chamber is to add auxiliary fuel when the temperatures drop below a minimum level and to add air when the temperatures rise above the maximum level.

The controlling of the air flows in the upper and lower chamber is extremely important in order to minimize the peaking activity and to provide a uniform flow of gas. This is important for controlling pollution performance as well as efficient energy recovery.

The noncombustible portion of the waste and the carbonous residue from the reaction remain in the lower chamber. The noncombustibles are rendered sterile by the relatively high temperatures while the carbonous material is further oxidized by incoming air.

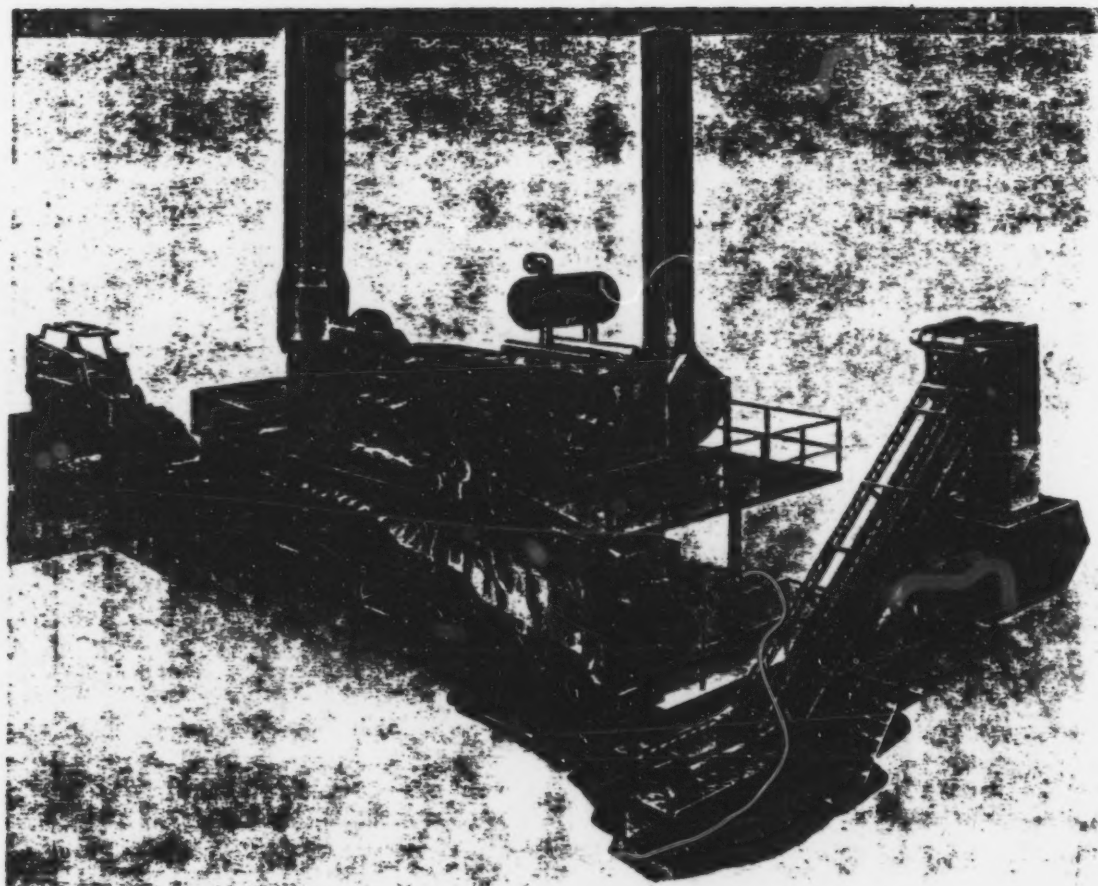
To achieve continuous operation, the systems are equipped with automatic ash removal. The ash is removed continuously from the primary combustion chamber and deposited in a quenching tank where dragout conveyors remove the cooled ashes and discharge them into a receptacle for transportation to the landfill.

Incineration modules are available for municipal systems in sizes of 25 tons per day to 100 tons per day. A number of units can be placed in the same facility to produce systems of up to 400 tons per day.

To incorporate energy recovery, waste heat recovery boilers of either a fire tube design or water tube design are utilized. Exhaust gases from the controlled air combustion modular units are drawn through the waste heat recovery boilers by an induction draft fan. Systems that employ heat recovery modules operate as described above, except that the exit gas temperatures from the secondary chamber are not allowed to exceed 1800°F.

Modular Refractory Incinerators

The designs of some municipal incinerators incorporate the use of modular refractory combustion furnaces that consist of a refractory-lined primary chamber and a refractory-lined secondary chamber.



Modular Controlled-Air Incinerator

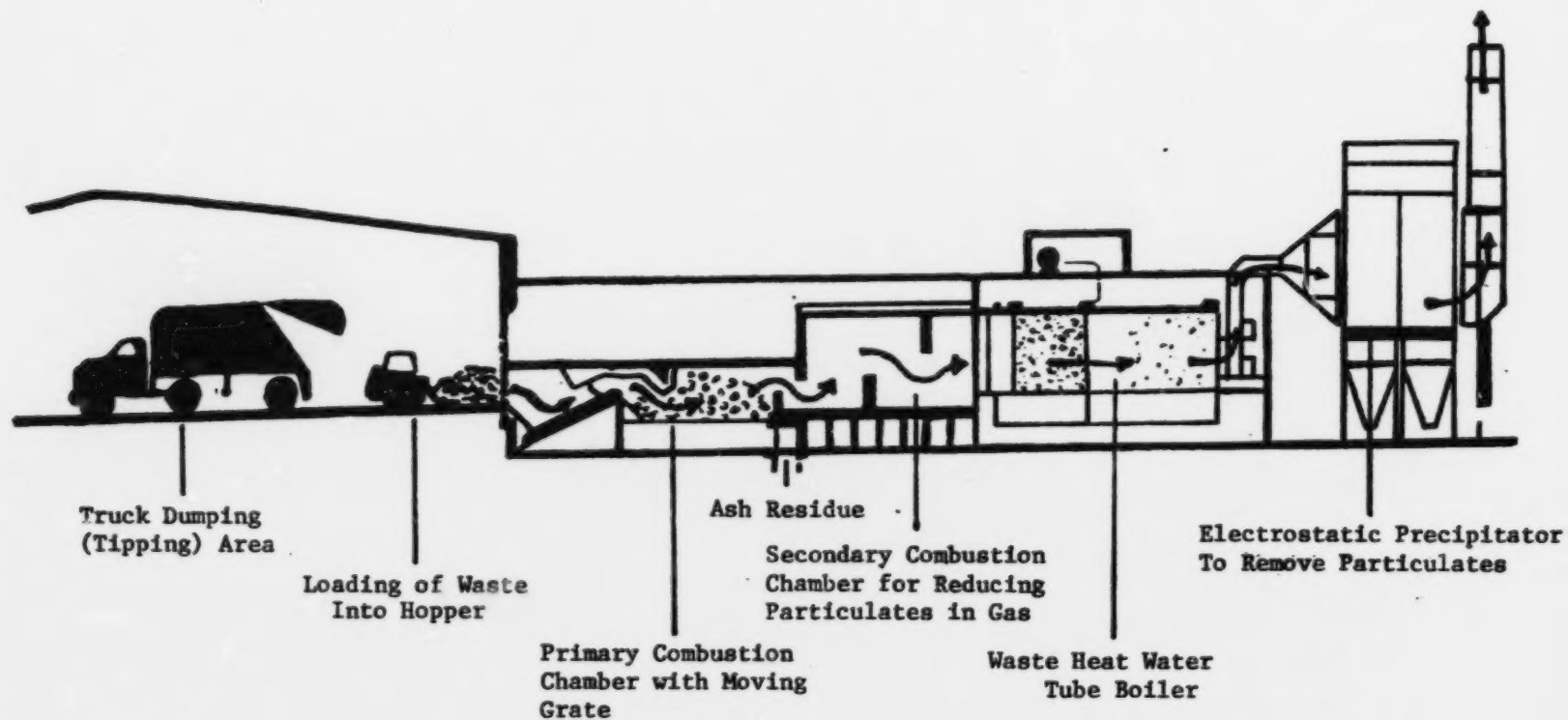
The front of each modular combustion cell consists of a gravity feed hopper. The unsorted municipal solid waste is deposited in the hopper and is metered into the furnace by the means of a refuse feed conveyor. The waste is deposited on a moving grate. The grate is sloped downward, and the entire grate reciprocates forward and backward in alternating sections. The frequency of reciprocation is varied to permit a net forward speed of 0 to 5 feet per minute with a completely loaded grate. Material is advanced on the grate as it moves backward against the bulk of the charged material and the back plate. Residence time in the furnace is maintained to allow volume reductions of about 90 to 95 percent. The individual sections of the grate have holes uniformly spaced to permit adequate distribution of underfire combustion air.

Underfire air fans supply combustion air to the furnace. The fans are equipped with variable inlet dampers to regulate the amount of underfire air. The induced draft fans produce a negative pressure in the unit, and pressure sensors located in the unit provide modulating air control.

The combustion air is pulled from the refuse storage area through the modular combustion cell, thus eliminating odors and controlling dust in the facility.

Overfire air is supplied to aid in the control and combustion of suspended particulate matter.

The design of the grate system combined with the underfire air system provides ideal combustion atmosphere and retention time to maximize the release of volatile and fixed carbon in the municipal refuse. The negative pressure furnace atmosphere, through the use of excess air and hot refractory, provides a controlled temperature zone. The resultant ash is primarily made up of glass, ceramic, stone, and metals. The ash



Modular Refractory Incinerator - Boiler System

residue drops from the end of the grate into a water quenching tank where a dragout conveyor removes the ash and deposits it in a container for transportation to the landfill.

Temperature control is achieved by regulating the amount of heat retained in the furnace. By opening the dampers between the furnace and the induced draft fan, less gas is pulled through the furnace; this, in turn, increases the temperature within the furnace. By closing the dampers, the induced draft fan can be used to draw gaseous products of combustion through the furnace, thus decreasing the temperature within the furnace.

Air is directed along the walls of the furnace to maintain the wall temperatures below ash fusion temperature, thus eliminating ash slag accumulation on the furnace walls. To prevent clinker formation (slagging) and clinker adhesion to the grates, close control of the furnace temperature is maintained. The design of the grate and the large volumes of air that pass through the grates keep the fuel bed temperatures next to the grates below the slag melting point.

The gaseous products of combustion pass from the primary combustion chamber over a bridge wall and under a drop arch into a secondary combustion chamber. This chamber provides the proper turbulence and retention time to ensure complete particulate burnout without the use of auxiliary fuel. Gas velocities in the secondary chamber are reduced prior to leaving to allow particulate settling before the gases pass to the waste heat recovery boiler.

Gases leaving the secondary combustion chamber pass through a waste heat boiler that absorbs a large portion of the heat from the gas stream. The waste heat boiler also serves the purpose of preconditioning and cooling the gases to ensure against air pollution.

The exiting gases from the boiler pass through an air pollution device that is designed to ensure compliance with all existing State and Federal emission standards. The air pollution device removes the sub-micron particulate in the gases, and then the gases exit through a stack to the atmosphere.

A bypass arrangement is provided to allow the combustion of refuse if the boiler should be inoperable. Within the bypass is a refractory column scrubber in which the gas stream passes through a sheet of water emanating from a slot in the roof that extends across the full width of the chamber. At the end of the scrubbing section, the gas stream is deflected by a bank of tubes through a drying arch and passes through the induced draft fan; the gas stream then passes through the air pollution control device and exits through a stack to the atmosphere.

The fly ash from the air pollution equipment is conveyed to a settling basin, which is part of a clarifier tank where all water in the system flows. A dragout conveyor removes the fly ash material from the clarifier and deposits it in an appropriate container for transportation to the landfill. This enclosed circulating water system ensures that no water pollution is incurred.

The incineration modules are available in sizes from 25 tons per day up to 200 tons per day. Various combinations can provide systems up to 800 tons per day.

Rotary Waterwall Combustor-Boiler

The rotary waterwall combustor combines the technology of a rotary kiln-type furnace with that of a waterwall furnace. The unit is basically a rotary kiln with a watertube wall instead of the refractory wall used in the rotary kiln. The rotary combustor is a hollow cylinder made up

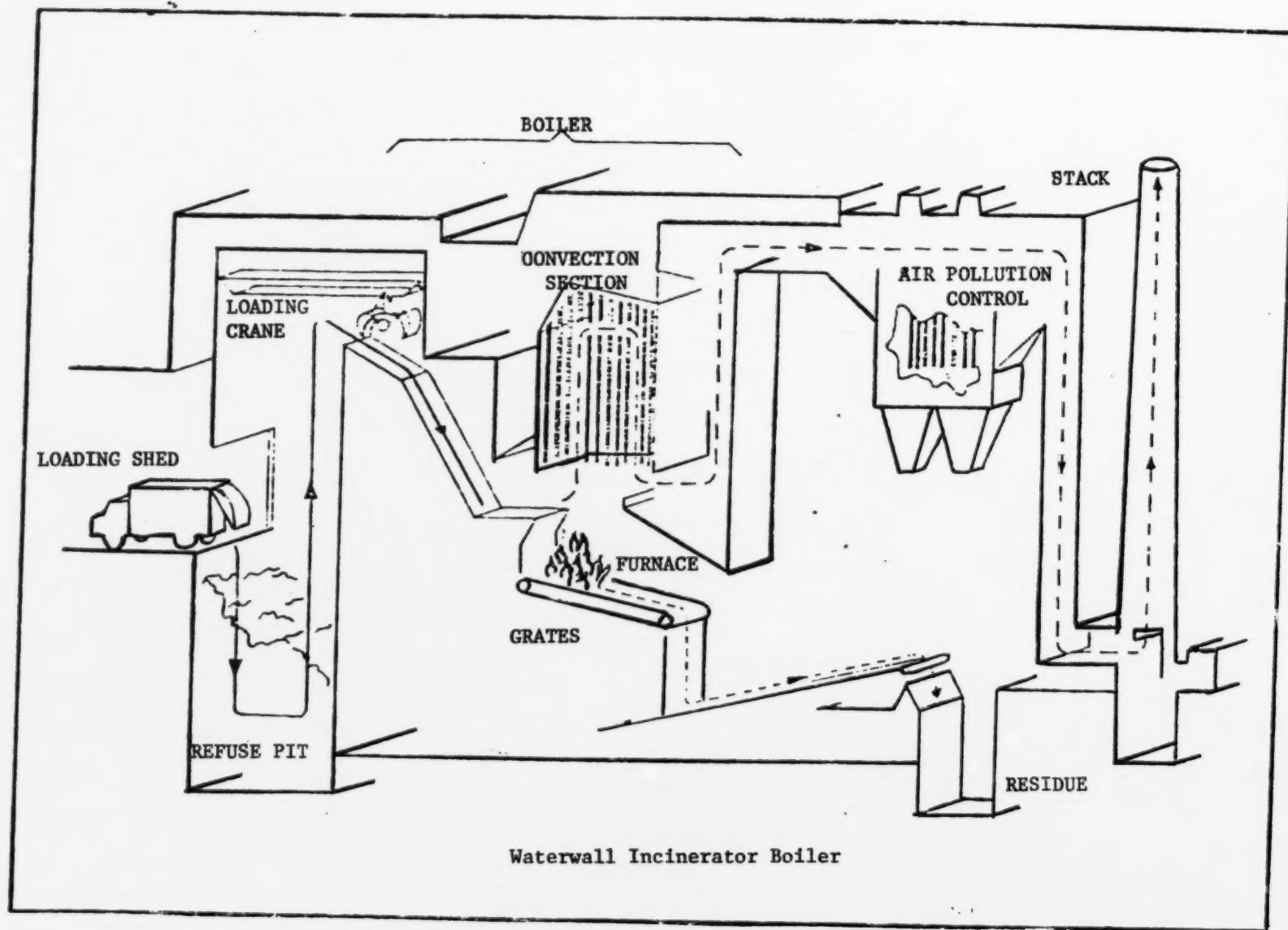
by alternately joining steel tubes and steel plates with a number of pinholes. Each end of the boiler tubes is connected to ring headers. The cylinder is supported in a 6° inclined position by rollers and turns slowly (1/6 rpm) by a driving unit.

The waste is fed from the upper end of the rotary combustor and is slowly and continuously overturned and stirred by the rotation, while combustion air heated through an air preheater is supplied through the pinholes in the rotary combustor wall. The air is supplied evenly throughout the rotary combustor in order to facilitate the drying and the incineration of the waste. The waste is discharged from the end of the combustor onto a grate at the base of a waterwall boiler. Additional retention time is obtained on the grate before the ash is deposited into a quenching system. In order to provide optimum air distribution, a separate wind box is provided around the bottom of the combustor.

Boiler water is circulated inside the tubes which constitute the rotary combustor wall by a forced circulation system in order to protect the wall from the influence of high temperature and to recover the energy in the form of steam. The circulation water is fed to the rotary combustor from the water drum of the boiler through a rotary joint and is returned to the steam drum.

Waterwall Incineration-Unprocessed Waste

This technology was developed more than 50 years ago for use with low grade coal and other types of waste fuels, but it has only been used for municipal solid waste for about 20 years. However, in Europe and Japan, its acceptance has been rapid and widespread; and several hundred units have been built in sizes ranging from 60 to 2,600 tons per day.



Municipal solid waste is deposited on a tipping floor or in a large storage pit from which it is transferred to the furnace feed hopper. From the feed hopper, the waste is fed into the furnace where it burns as it moves continuously through the furnace. The combustion residue falls off the end of the grate where it is quenched with water and then conveyed to trucks for transportation to landfill.

The furnaces are enclosed by closely spaced, water filled tubes. Water circulating through the tubes recovers heat radiated from the burning waste. Integrally constructed heat recovery boilers generate steam while reducing the temperature and the volume of the exhaust gases. The additional sections of the boilers consist of various zones or tube packages referred to as heaters, economizers, reheaters, etc., depending on the function of the particular zone.

In the combustion process, oxygen (air) is required to burn the fuel and release the heat. Air is introduced into the furnace beneath the grates (underfire air) to aid in the combustion and to help keep the grates cool. Air is also introduced above the fuel bed (overfire air) to promote mixing of the gases (turbulence) and to complete the combustion in the furnace.

The combustion gases, after being cooled as they pass through the various boiler sections, are passed through air pollution control devices (generally electrostatic precipitators) and are vented to the atmosphere through a stack. In a well designed and operated unit, more than 94 percent of the available energy can be released through the combustion process.

Environmental Aspects

There are four basic impacts to be considered in the establishment of an incineration waste heat recovery facility. These are: atmospheric emissions, wastewater disposal, residue disposal, and local and in-plant environmental impacts.

Atmospheric emissions are produced by the combustion of municipal refuse fuel. Municipal refuse is far from being an easily characterized homogenous fuel. It varies widely depending upon the geographical, seasonal, and weather-related factors. Refuse is an inherently low sulfur fuel containing less than one tenth of the amount of sulfur found in typical low sulfur coals. Sulfur dioxide, carbon monoxide, and unburned hydrocarbons are not considered a problem in most resource recovery boiler systems due to the high flame turbulence and combustion time. Chlorine in municipal refuse is usually in the form of sodium chloride and chlorinated synthetics which may present corrosion problems from acid formation if temperatures are not strictly controlled.

Particulate matter has been the primary concern of most waste-to-energy systems. However, well designed pollution control devices can remove 99 percent plus of the particulate matter, thus minimizing the facility's impact on local air quality standards.

As part of the overall impact evaluation of a resource recovery facility, the pollutants emitted by motor vehicles associated with the delivery of refuse to the plant must be analyzed to determine the concentrations of carbon monoxide, hydrocarbons, and oxidants in the vicinity of the plant.

Water is utilized to some extent in all resource recovery facilities. The discharge of this wastewater produced by the operation of the

facility should be considered in any environmental assessment study. These discharges include processing wastewaters, wash waters, and waters associated with the combustion process such as cooling towers and boiler blowdown.

The conversion of refuse to energy generally reduces the volume of municipal solid waste by 90 percent, thus increasing the life of existing landfills. The bottom ash and fly ash produced by these waste-to-energy systems has been found to contain trace elements such as beryllium, mercury, cadmium, and lead. However, the impact on local environment is presently considered minimal when the ash is disposed of in a properly designed and operated landfill.

Local and in-plant environmental impacts include: the containment of the malodorous air within the plant; maintenance of the carbon monoxide levels in the tipping area within OSHA limitations; fogging and disposition of solids produced by the operation of cooling towers; and noise associated with the operation of plant and the delivery of refuse to the facility. Most systems prevent malodorous air from escaping to the ambient by keeping the tipping area at a negative pressure and then drawing this air through the waste incineration system whereby the malodorous substances are destroyed.

Fresh ventilating air in the facility can control exhaust gases from refuse delivery trucks while odors from combustion residue can be minimized by providing clean burnout followed by thorough quenching.

Proper engineering can also minimize noise levels at the facility incurred from both waste handling vehicles and waste processing activities. Any equipment that creates noise disturbances above ambient levels at the property line of the facility or above OSHA standards for workers must be

shielded in order to reduce these levels. The flow of waste handling vehicles to and from the facility should be designed to minimize effects on residential and other sensitive areas of the community.

MATERIALS SEPARATION AND RECOVERY

In an effort to extract the maximum revenue from solid waste as a resource, as well as to produce a more usable and flexible fuel for various types of furnaces, considerable investigation has been conducted on separating the raw refuse into its major components. Various systems have been developed for breaking up (shredding or milling) the bulk waste to extract the metals, glass, and both the light and heavy combustibles.

Presently, extensive recovery of materials from municipal solid waste is practiced only on a limited basis. Other than ferrous metals, material recovery technology can be considered in the stages of full scale "prototype."

The recovery of ferrous metals is practiced widely on municipal solid waste. The important consideration in ferrous recovery, as in the recovery of other materials, is the final preparation of a product suitable for sale to the marketplace.

Obviously, there are components in municipal solid waste streams that have a value as secondary or recyclable materials. The capital expenditure and operating expense to extract these in some sort of centralized "resource recovery" plant is only worthwhile if a net profit can be shown on the venture.

Although recovery of aluminum, other nonferrous metals, paper and glass cullet is not recommended at this time, such additional recovery should be reconsidered in the future as the experience and results of more extensive material recovery efforts become known.

In any combustion plant for municipal waste, there is some front end separation, even though it may be as simple as viewing the dumped waste and removing the appliances, bicycles, and furniture items that households have added to their trash piles.

All analyses show that the most valuable resource that can be extracted from municipal waste is energy. The burning of the combustible segment as a low grade, bulk fuel has been proven both economically and technically feasible in many plants of various designs throughout the world with the production of heat, steam, or electricity as the final product.

The most useful aspects of waste separation and size reduction are: to improve the characteristics of such fuels; to make them more homogeneous with better handling and burning characteristics; to improve fuel values and volatile release rates; and, with smaller ash residues, to handle these at the completion of combustion. The amount of effort and expense devoted to this end will differ with the type of combustion and boiler system being considered as will the rate of return on the investment.

If the efficiency of the fuel and the production of the net energy (the energy balance of the entire system) can only be improved a few percentage points by a large increase in capital and operating cost, the sophistication is not worthwhile.

Some systems have been developed where the additional capital and operating cost can be recaptured rather quickly by improving the energy output of the resultant fuel. If additionally there is a market for the other separated and recaptured materials (such as metals and glass) that will pay a substantial percentage of the operating cost, the whole

approach begins to look attractive. In general, a 500 ton per day system would be required before this approach would be economically viable.

Handpicking

This step may be inserted at the beginning of a materials or energy recovery system in order to allow for inspection and low-level paper recovery. When municipal solid waste first enters the energy and resource recovery facility, old newspapers and corrugated boxes are handpicked from a conveyor belt prior to processing in the facility. In this way, a small but saleable amount of clean paper is recovered while allowing for simultaneous inspection of the waste stream from materials, which could cause possible harm in the energy recovery system.

The newspaper and corrugated boxes could be fed separately into a baler in order to facilitate subsequent storage and shipment for sale.

Mechanical Separation

Mechanical separation of waste components universally follows certain basic steps, the first of which is to reduce all the waste to a predetermined size range by shredding or milling it either on a dry basis (the most common method) or by wet pulping. Shredding or milling may be on an extremely coarse basis which reduces the waste stream into large pieces of 4 to 8 inches in size, or it may be multistage that literally reduces the entire waste stream to pieces of under 1 inch in size. As the particle size decreases, more process stages and equipment are required, thus increasing the capital and operating expense.

Once the design size reduction is achieved, the waste is then moved through an air classifier. The lightweight paper and plastic, along with many combustible organics, can be lifted away from the heavier

items (such as metals, glass, and heavier combustibles). As much as 60 percent of the total stream is in the form of light combustibles and can be separated out in this system.